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(54) Abstract Title
Determination of injected fuel quantity in an internal combustion engine

(57) A method of determining the injected quantity of fuel in an internal combustion engine comprises the steps of measuring combustion chamber pressures by pressure sensors (14 to 17) and crankshaft angular settings by an angle sensor (18), the measured pressure values being synchronised with the measured settings and the indicated work, which corresponds with the difference between the work produced and the work done by the cylinder, being calculated from the synchronised pressure values. The quantity of the injected fuel can be ascertained from this indicated work.

Fig. 1

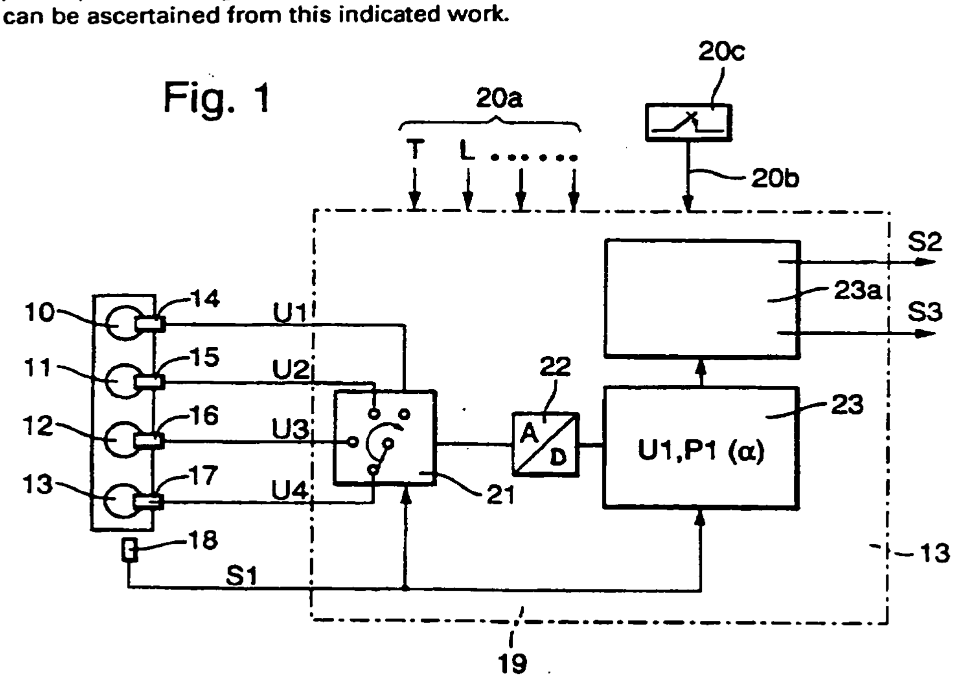

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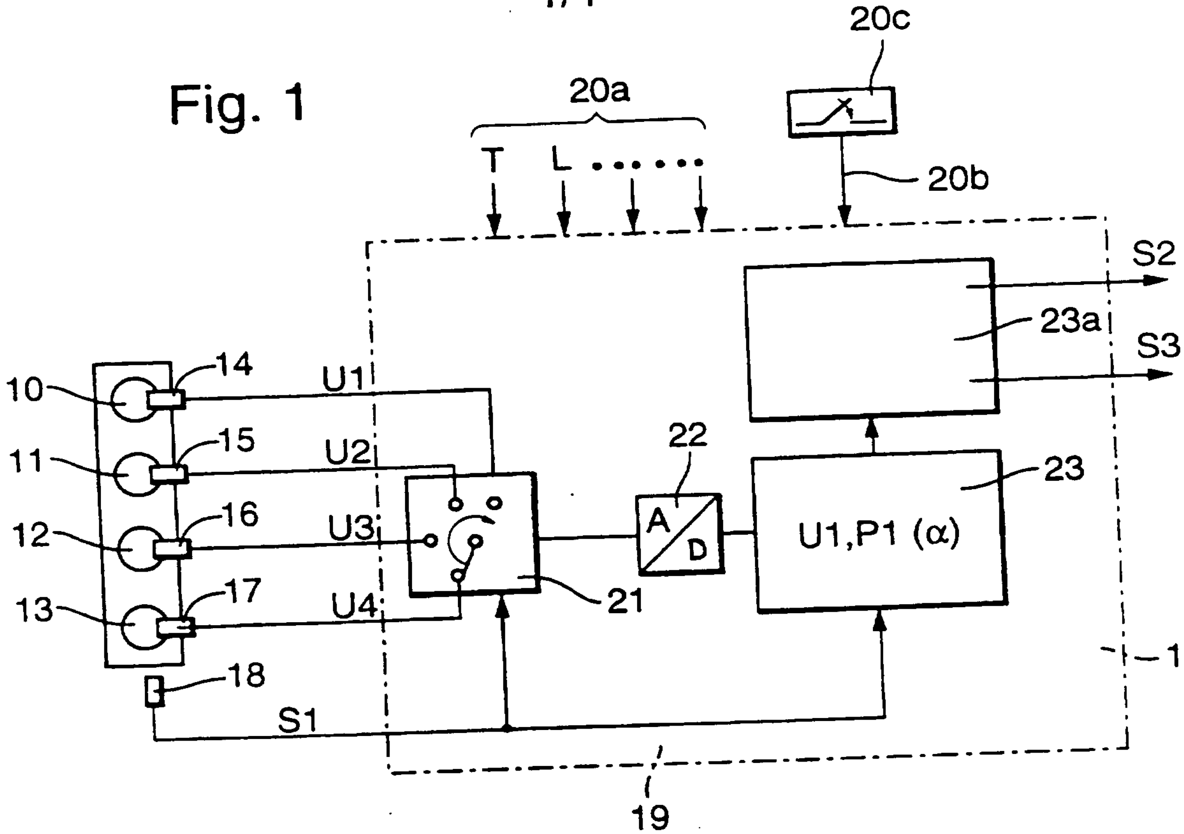
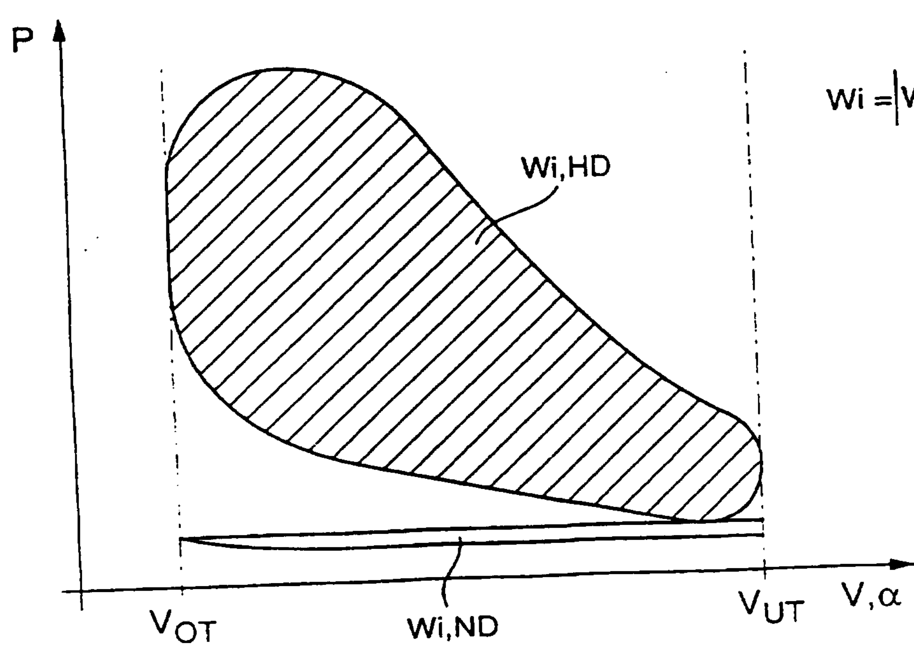
Fig. 1



20a
20c
T
L
20b
S2
23a
S3
10
14
U1
11
15
U2
22
23
12
16
U3
A
D
U1,P1 (α)
13
17
U4
21
13
18
S1
19

Fig. 2



P
Wi = |Wi,HD| - |Wi,ND|
Wi,HD
V,α
V_{OT}
Wi,ND
V_{UT}

DETERMINATION OF INJECTED FUEL QUANTITY IN AN INTERNAL COMBUSTION ENGINE

The present invention relates to a method and determining means for determining the injected quantity of fuel in an internal combustion engine.

For determining the quantity of fuel injected into a cylinder of an internal combustion engine, it is a common practice to evaluate the output signal of, for example, a conveying signal sensor or needle stroke sensor which records the movement of the injection valve. Such an evaluation is described in EP-0 444 055 in conjunction with a method for regulation of a diesel engine. In such an evaluation, the closing time of the injection valve is ascertained. This defines the duration of injection and, with knowledge of a given cross-section of the injector nozzle, the quantity of injected fuel. Quantity determination on the basis of the output signal of such a sensor makes it possible, as in the case of quantity determination by way of models and auxiliary magnitudes, to achieve a reliable regulation of the engine, since the ascertained quantity of injection can be used as an actual magnitude for regulation. With such an actual magnitude, it is possible to regulate towards a torque which corresponds with the wish of the driver of a vehicle fitted with the engine. Such a wish is recognised by way of the accelerator pedal setting. However, ascertainment of the actual torque, which corresponds with the quantity of fuel, requires a number of corrections and thus computing performance from the engine control system. A variation in the fuel quality cannot be recognised, whereby a loss of power or torque can occur in the case of reduction in the calorific value of the fuel. If the heating value of an unknown fuel is greater than actually assumed, impermissible loading of the drive train can occur. These problems can be avoided only if, in place of a conveying signal sensor there is used a sensor which reproduces the combustion processes more reliably.

Sensors which reliably reproduce the combustion course in the cylinder of an internal combustion engine are combustion chamber pressure sensors arranged in the engine cylinders. Information, on the basis of which regulation of the engine can be carried out, can be obtained from the output signals of combustion chamber pressure sensors or cylinder pressure sensors. Such an engine regulation method, in which the output signals of cylinder pressure sensors are evaluated, is known from, for example, DE-OS 43 41 796. In this known regulation method, the combustion chamber pressure course in the case of combustion is compared with the compression pressure course without combustion. The

difference between these pressure courses is integrated up and a setting magnitude for the regulation of the position of the combustion is formed from the integral. Operation can be performed with the aid of such a regulation.

According to the present invention there is provided a method and device for ascertaining the injected quantity of fuel in an internal combustion engine with at least one cylinder pressure sensor which supplies a voltage signal proportional to pressure, a crankshaft angle sensor which delivers a signal representative of the crankshaft setting and evaluating equipment which synchronises the voltage signal proportional to pressure with the crankshaft angle signal, characterised in that the indicated work, which corresponds with the difference between the high-pressure work and the charge change work, is computed from the cylinder pressure values referred to crankshaft angle, and the quantity of the injected fuel is ascertained from the indicated work.

Such a method and device may have the advantage that a simple and reliable regulation is possible, since the evaluation of the output signals of combustion chamber pressure sensors does not require large corrections and thus does not need significant computer performance. Moreover, combustion chamber pressure sensors are more favourable in cost than conveying signal sensors. The particularly precise reproduction of the combustion processes by the pressure sensors makes possible a particularly advantageous regulation of the engine. These advantages result from the fact that the cylinder or combustion chamber pressure courses are referred to the crankshaft angle and the indicated work, which corresponds with the difference between the high-pressure work and the charge change work, is computed therefrom, the quantity of injected fuel then being ascertained from the computed indicated work.

Preferably, the evaluating equipment comprises a microprocessor of a control system of the engine, which is preferably a diesel engine.

For preference, the computation of the mass of the injected fuel takes place from the indicated work subject to consideration of the heat value of the injected fuel. Expediently, the torque, which is produced at the crankshaft of the engine due to combustion, is ascertained from the mass of the injected fuel and/or the ascertained indicated work. In addition, the torque ascertained from the cylinder pressure can be compared with a torque

computed in an engine control system from an accelerator pedal setting and, in the case of a deviation, the mass of the injected fuel can be so varied that the deviation is reduced.

For preference, a respective combustion chamber pressure sensor is arranged in each cylinder of the engine and regulation of fuel injection is carried out individually for each cylinder. Moreover, the output signals of the combustion chamber pressure sensor or sensors can be used for ascertaining of further magnitudes dependent on combustion processes in cylinders of the engine.

Further advantages of the invention can be achieved by the above-mentioned preferred features. One of these further advantages is that the use of fuel of varying qualities is also possible without an individual fuel recognition being required. It is also advantageous that power may be able to be increased up to the limit of the permissible drive train loading or, in the case of diesel engine, up to the soot limit without concern about overloading. These advantages are possible because the evaluation of the combustion chamber pressure course enables the energy conversion be recognised directly. The use of fuels with different calorific values leads to different combustion courses which, in turn, lead to corresponding pressure courses which are evaluated directly. Thus, the torque produced by the combustion can be ascertained from the cylinder pressure course or the combustion chamber pressure course without knowledge of the fuel composition. With knowledge of the composition or calorific value of the fuel used, the quantity of the fuel can be ascertained very accurately from the indicated work.

Since the output signals of pressure sensors have characteristic features, they can be used in additional ways. For example, it is possible to additionally perform recognition of detonation, since the outputs signals have components typical of knocking in certain ranges. By evaluation of the height and/or position of the maximum value of a knock signal, cylinder recognition can be carried out and recognition of ignition misses is also possible. The rotational speed of the engine can be ascertained by evaluation of the time spacing of successive signal maxima or pressure maxima. In particularly advantageous manner, the output signals of the pressure sensors can be used for torque regulation instead of torque control.

An example of the method and an embodiment of the determining means of the present invention will now be more particularly described with reference to the accompanying drawings, in which:

Fig. 1 is a block diagram of determining means embodying the invention; and

Fig. 2 is a diagram showing the relationship between pressure and volume in a cylinder and the indicated work for a work cycle of an internal combustion engine.

Referring now to the drawings there is shown in Fig. 1 determining means for determining the injected quantity of fuel in an internal combustion engine with at least one combustion chamber pressure sensor. Individual cylinder pressure sensors 14, 15, 16 and 17, which deliver pressure-proportional output voltages U1, U2, U3 and U4, are arranged in the combustion chambers of the cylinders 10, 11, 12 and 13. Also present is a crankshaft angle sensor 18, which delivers an output signal S1 indicative of engine crankshaft angle α.

The output voltages of the pressure sensors 14, 15, 16 and 17 and the output signal S1 of the angle sensor 18 are fed to a control device 19, which processes these signals, of the engine. Further signals, for example temperature T, load L, etc., can be fed to the control device 19 by way of inputs 20a and are likewise processed further in the control device 19. A signal, which represents the setting of an accelerator pedal of a vehicle fitted with the engine, is fed to the control device 19 by way of an input 20b. This signal is ascertained with the aid of a pedal setting transmitter 20c, for example a potentiometer. The pedal setting signal represents the engine torque or acceleration desired by the vehicle driver and is thereby a measure of fuel quantity to be injected. The processing of the pedal setting signal in the control device 19 is described more closely in the following.

The control device 19 comprises a multiplexer 21, by way of which the output voltages of the pressure sensors 14, 15, 16 and 17 can be fed selectively to an analog-to-digital converter 22. The switching-over of the multiplexer 21 takes place in dependence on crankshaft angle and is triggered by appropriate drive control actions of the control device 19. If a multichannel analog-to-digital converter is used, the multiplexer 21 can be dispensed with. Evaluation of the signals takes place in a microprocessor 23 of the control device 19, which in dependence on ascertained magnitudes delivers control signals S2

and S3 by way of an output unit 23a to different components of the engine, for example injection signals to an injection system.

The exact ascertaining of the torque or the injected fuel quantity takes place in the microprocessor 23 of the control device 19. For this purpose, the pressure-proportional electrical voltage signal, for example U1, is initially synchronised with the crank angle α. Accordingly, pressure values, for example $P1(\alpha)$, which are referred to crankshaft angle and from which the indicated work can be computed, are available to the microprocessor 23. This indicated work corresponds with the indicated torque. For computation of the indicated work, the cylinder volume, which is dependent on crankshaft angle, is computed from the signal of the angle sensor 18 and from engine geometry data. With these volume data and the pressure data supplied by the pressure sensors, the integral pdV, which corresponds with the indicated work Wi as the difference between the high-pressure work Wi, HD and the charge change work Wi, ND, is formed over a crankshaft interval of -360° to +360° crankshaft angle (KW). The relationship between combustion chamber pressure and volume as well as the indicated work are illustrated in Fig. 2. The volumes at the top dead centre and bottom dead centre are denoted by V_{OT} and V_{UT}, respectively. The work thus ascertained correlates with the injected quantity of fuel and with the torque supplied due to combustion on the presumption that the fuel quality is known and constant.

In the case of changing fuel qualities and thus in the case of changing calorific values, the injected quantity can be tracked by comparison with the previously applied indicated work for a comparison fuel. A comparison with the quantity computation usual nowadays can also make a tracking of that kind possible. For this purpose, however, the engine would need to have not only combustion chamber pressure sensors, but also a conveying signal sensor.

In a special form of engine regulation, for example of a diesel engine, the injected quantity of fuel is not ascertained, but fuel is injected until the desired torque preset by the driver is achieved. This desired torque is computed from the setting of the accelerator pedal sensor by the control device 19 or by the microprocessor 23 of the control device 19. In order for this computation to be possible, the maximum permissible torque must be ascertained in an application phase before starting up the engine and be so interlinked with the accelerator pedal settings that the maximum permissible torque is associated with a setting in which the pedal is depressed 100%. Since the pedal setting is usually

ascertained with the aid of a potentiometer, an abutment of the potentiometer can be associated with the maximum permissible torque. A torque limitation is superimposed on the signal indicative of driver wish (conversion of accelerator pedal setting into quantity or torque) and prevents overloading of the engine.

A regulation individual for each cylinder can take place if a combustion chamber pressure sensor is disposed in each cylinder 10, 11, 12 and 13 of the engine, for example a diesel engine. In the case of such a regulation, the torque wish computed from the setting of the accelerator pedal sensor serves as target value and the torque computed from the measured combustion chamber pressure serves as actual value.

CLAIMS

1. A method of determining injected fuel quantity in an internal combustion engine, comprising the steps of measuring combustion chamber pressure in a cylinder of the engine by a pressure sensor and crankshaft angular setting by an angular setting sensor, synchronising measured values of pressure with measured values of angular setting, calculating from the synchronised pressure values an indicated work value corresponding to the difference between high-pressure work and charge change work, and ascertaining the injected quantity of fuel from the calculated indicated work value.

2. A method as claimed in claim 2, wherein the engine is a diesel engine and the steps of synchronising, calculating and ascertaining are carried out by a microprocessor of a control system of the engine.

3. A method as claimed in claim 1 or claim 2, wherein the step of ascertaining is carried out with consideration of the heat value of the injected fuel.

4. A method as claimed in any one of the preceding claims, comprising the further step of ascertaining torque at the engine crankshaft from at least one of the calculated indicated work value and the ascertained injected fuel quantity.

5. A method as claimed in claim 4, comprising the further steps of calculating engine torque in dependence on the setting of the accelerator pedal of a motor vehicle fitted with the engine, comparing the calculated torque with the ascertained torque to detect difference therebetween and varying the injected quantity of fuel to reduce any such detected difference.

6. A method as claimed in any one of the preceding claims, wherein the step of measuring combustion chamber pressure is carried out individually for each of a plurality of cylinders of the engine by a respective pressure sensor.

7. A method as claimed in any one of the preceding claims, comprising the further step of determining at least one engine operating parameter dependent on combustion from the measured pressure values.

8. A method as claimed in claim 1 and substantially as hereinbefore described with reference to the accompanying drawings.

9. Determining means for determining injected fuel quantity in an internal combustion engine, comprising means for measuring combustion chamber pressure in a cylinder of the engine by a pressure sensor and crankshaft angular setting by an angular setting sensor, synchronising measured values of pressure with measured values of angular setting, calculating from the synchronised pressure values an indicated work value corresponding to the difference between high-pressure work and charge change work, and ascertaining the injected quantity of fuel from the calculated indicated work value.

10. Determining means as claimed in claim 9, wherein the engine is a diesel engine and the determining means comprises a microprocessor of a control system of the engine.

11. Determining means as claimed in claim 9 or claim 10, the determining means being arranged to ascertain the injected fuel quantity with consideration of the heat value of the injected fuel.

12. Determining means as claimed in any one of claims 9 to 11, comprising means for ascertaining torque at the engine crankshaft from at least one of the calculated indicated work value and the ascertained injected fuel quantity.

13. Determining means as claimed in claim 12, comprising means for calculating engine torque in dependence on the setting of the accelerator pedal of a motor vehicle fitted with the engine, comparing the calculated torque with the ascertained torque to detect difference therebetween and varying the injected quantity of fuel to reduce any such detected difference.

14. Determining means as claimed in any one of claims 9 to 13, comprising individual pressure sensors for measuring the combustion chamber pressures of a plurality of cylinders of the engine and means for individually regulating fuel injection into each cylinder.

15. Determining means as claimed in any one of claims 9 to 14, comprising means for determining, from the measured pressure values, at least one engine operating parameter dependent on combustion.

16. Determining means substantially as hereinbefore described with reference to the accompanying drawings.

17. An internal combustion engine provided with a system for controlling operation thereof, the system comprising determining means as claimed in any one of claims 9 to 16.

The Patent Office

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Application No: GB 9823892.6
Claims searched: 1-17

Examiner: Steven Davies
Date of search: 27 January 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): G1N-NAAJCR

Int Cl (Ed.6): F02B-77/08 ; G01M-15/00

Other: Online databases: WPI, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	EP 0484553 A1 (JAPAN ELECTRONOC CONTROL)	
A	EP 0463537 A2 (NOBIS)	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.